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A survey of nocturnal reptiles of Robin Falls, Northern Territory: implications of *Bufo marinus*

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Abstract

Twenty-two species of nocturnal reptiles were identified in the Robin Falls area during one year (2001-02) of regular observational surveys. More reptiles were observed during the build-up and early dry season compared to the wet and the dry seasons. The greatest number of individuals (42) and species (15) of nocturnal reptiles were recorded during the build-up (Sept.-Nov.), during which average night-time temperatures of 28°C, absolute humidity of 19.07g/m^3, and total rainfall of 190 mm were experienced. While comparisons of seasonal climatic factors produced trends, temperature, humidity and rainfall did not show any significant relationship with the number of observed reptiles. Nearly one third of the nocturnal reptile species listed in the Robin Falls area are considered to be susceptible to the Cane Toad *Bufo marinus*. This study provides preliminary quantitative baseline data from which to examine any future detrimental effects of the Cane Toad on nocturnal species of reptiles in the Robin Falls area.

Introduction

Robin Falls is a small tourist haven, located near the Adelaide River Township, which lies about 120 km south of Darwin in the Northern Territory (NT). The falls are reached via Dorat Road, which turns off the Stuart Highway near the Adelaide River Township. A 15-minute walk from the Robin Falls car park leads along a creek edged with monsoon forest. The creek originates from a spring above the escarpment and carves its way through swamp and open woodland until it clears the edge of the plateau and plunges into a large rock basin in the valley below. After the valley, the creek passes underneath Dorat Road and heads towards lower floodplains. Dorat Road travels through plateau and lowland wetland and over many tributaries similar to that of Robin Falls, all of which feed into the Adelaide River. Plant communities present in this region include woodland, monsoon forest, swampland and floodplain.

Robin Falls is privately owned, but graciously opened to visitors, and managed by the Landcare Council NT and other community groups such as Coomalie Water Watch and Greening Australia. There is little evidence of disturbance in the area except for a few small cleared areas for camping sites, a short gravel access road and a narrow

500 m walking track leading to the falls, and little invasion by weedy plant species. In recent years, fires have occurred every 1–2 years (fire events noted in 2000 and 2001). Dorat Road passes many privately owned properties that show little evidence of development. There is a banana plantation not far from the Adelaide River Township but most properties appear unaltered, with little (generally pastoral) or no land use.

A compilation of nocturnal species of reptile that have been identified (during 1911–2002) in the Robin Falls area is available from the Biological Records Scheme (BRS), set up by the Parks and Wildlife Commission of the Northern Territory (PWCNT). However, comprehensive scientific research, such as long-term ecological studies, is lacking in this area. This is unfortunate given that the Cane Toad *Bufo marinus* is slowly progressing towards Darwin. Cane Toads were introduced into Queensland in 1935 to act as a biological control for the beetle *Dermolepia albohirtum*, which is a pest in sugar cane crops (Straughan 1966). While ineffective at controlling the cane beetle, the Cane Toad has effectively invaded much of the north-eastern coast and hinterland of Australia. The toads possess large, paired parotid glands located dorsally on the neck, which produce a cocktail of toxic chemicals including biogenic amines and hallucinogenic compounds such as the bufogenins (Sutherland 1983, Edstrom 1992). The Australian native fauna have not co-evolved with these types of toxins, and anecdotal observations of species declines within areas of toad invasion and recent studies demonstrate that many Australian predators are adversely susceptible to these compounds (Covacevich & Archer 1975, Catling *et al.* 1999, van Dam *et al.* 2002). Currently, efforts are being made to conserve local species, such as the Quoll Recovery Plan under the Island Arks Project, which aims to provide safe havens, free from the impacts of exotic species, for native species (B. Rankmore pers. comm.). At the time of this research there had been no records of *B. marinus* in the Robin Falls area (Frogwatch 2004).

Dorat Road leading to Robin Falls is well known among Australian herpetologists for its reptile diversity. During one year of regular surveys in the Robin Falls area, we recorded observations of all nocturnal species of reptile. In this paper, we summarise the number of reptiles and species observed by season, and present an analysis of the relationship between the weather conditions and the number of nocturnal reptile species observed in each season. A preliminary list of nocturnal reptiles in the Robin Falls area is also presented, indicating which local species may be impacted by the Cane Toad.

Methods

Visual encounter surveys (VES) were conducted along line transects between 21:00 and 24:00 hours every 10 days from December 2001 to November 2002 (Crump & Scott 1994). Surveys were conducted on two transects: Dorat Road and Robin Falls (13° 21' 20"S, 131° 07' 17"E).

Dorat Road: the first transect was conducted along 15 km of bitumen road, starting from the Adelaide River township turnoff and ending at the Robin Falls turnoff. Reptiles were located from a car using headlamps and car headlights. The car traveled on average 40 km/hr, while the road and road shoulders were searched for reptiles.

Robin Falls: the second transect used the 500 m long walking track that begins at the Robin Falls car park and ends at the falls. Reptiles were searched for on foot using headlamps. Walking pace was slow, and 2 m on either side of the walking track were searched.

The VES were conducted at a consistent pace, and the focal area surveyed was within the predetermined radius to the left, front and right of the observer. The surveys did not involve shifting leaf litter or lifting and turning rocks and logs, thus allowing us to minimise habitat disturbance, to eliminate the risk of injury to the animal and observer from improper handling of animals, and to comply with the legal guidelines of the Parks and Wildlife Commission of the Northern Territory (PWCNT) (it is a criminal offence to handle native wildlife unless holding a PWCNT permit). All nocturnal species of reptile encountered were recorded (amphibians were not included in this study because they are a focus of a separate paper). Air temperature (°C) and relative humidity (%) were measured using a hand held meter (HM34C Vaisala), and rainfall was measured by a rain gauge.

Analysis

Four recognized seasons were used to compare species numbers; build-up (Sept.-Nov.); wet (Dec.-Feb.); early dry (Mar.-May); and dry (Jun.-Jul.). Results were collated to show the number of each species of nocturnal reptile found in each season, and statistically compared using ANOVA (Systat, SAS). Climatic variables and the numbers of species identified are presented graphically and correlated statistically using logarithmic regression, for poisson distributed count data (Systat, SAS). Since humidity is dependent on air temperature (Ta), for the purpose of statistical analyses relative humidity was converted to absolute humidity (AH) (g/m^3) using the Smithsonian water density table at the given ambient temperature (List 1971). The level of significance for all analyses was set at $p < 0.05$.

The list of reptile species that may be found in the Robin Falls area was compiled using information from Wilson and Swan (2003) on the geographical distribution of reptiles and from species listed in the BRS (1911-2002).

Results

Nocturnal species of reptiles observed in the Robin Falls area

Table 1 provides a summary of the names and numbers of each species encountered on line transects in the Robin Falls area each season. A total of 22 nocturnal reptile

species were recorded during one year of surveys (36 surveys). The Freshwater Crocodile *Crocodylus johnstoni*, was encountered along Anniversary Creek (a tributary crossed by Dorat Road); however, the species was excluded from any analysis because the tributary was not consistently surveyed for this species throughout the survey period.

Table 1. A list of the species and total numbers of each of the reptiles observed on Dorat Road and Robin Falls transects, summarised by season.

Species	Wet (Dec.-Feb.)	Early dry (Mar.-May)	Dry (Jun.-Aug.)	Build-up (Sept.-Nov.)
Gekkonidae				
Gehyra australis	3	1	2	4
Heteronotia binoei				2
Oedura marmorata				1
Strophurus ciliaris ciliaris		1	4	1
Pygopodidae				
Delma tincta	1			
Lialis burtonis		3		5
Pythonidae				
Antaresia childreni		4	1	3
Liasis mackloti	1			
Liasis olivaceus			1	3
Morelia spilota		1		
Acrochordidae				
Acrochordus arafurae		15		
Colubridae				
Boiga irregularis	1			2
Stegonotus cucullatus				1
Tropidonophis mairii		1		2
Elapidae				
Acanthophis praelongus				13
Brachyurhophis roperi	1			
Furina ornata	1	1	2	1
Pseudechis australis		1		2
Pseudonaja nuchalis		1		
Rhinoplocephalus pallidiceps				1
Suta punctata				1
Vermicella intermedia		1		
Number of species	**6**	**11**	**5**	**15**
Total number of reptiles	**8**	**30**	**10**	**42**

Comparisons between season and number of observed nocturnal reptiles

The numbers of nocturnal reptiles observed in each season were significantly different (ANOVA: $F_{3,32} = 9.538$; $p < 0.001$). The greatest number of reptiles (42) and number of species (15) were found during the build-up (Sept.-Nov.) (Table 1). The number of species identified during the build-up included over half of the total species (22) observed during the one year of surveys. The number of individuals encountered during the early dry was also high (30), but was dominated by a large number (15) of Arafura File Snakes *Acrochordus arafurae* found in Anniversary Creek. Despite the predominance of file snakes, the number of species observed during the early dry (11) included half the total number of species encountered during the entire survey period. Fisher's PLSD post-hoc tests (5% significance level) found no statistical difference between reptiles observed during the build-up and the early dry ($p = 0.1190$). The lowest numbers of reptiles were observed during the wet (8) and the dry (10) seasons, which were not significantly different (Fisher's post-hoc: $p = 0.7912$) between seasons. Despite the low numbers of animals observed during the wet, two species, the Northern Shovel-nosed Snake *Brachyurhophis roperi* and the Black-necked Legless Lizard *Delma tincta,* were encountered during this season only.

Results from analyses of variance found significant seasonal differences in all climatic factors (ANOVA Ta: $F_{3,32} = 20.834$, $p < 0.001$; AH: $F_{3,32} = 71.491$, $p < 0.001$; Rain: $F_{3,32} = 5.486$, $p < 0.004$). Night-time air temperature and absolute humidity were statistically higher in the wet, early dry and build-up than in the dry (Fisher's post-hoc: $p < 0.0001$) (Figure 1). While the wet season had similar average temperature and humidity to that of the build-up and early dry, total rainfall (816 mm) was greater than all other seasons (Fisher's post-hoc $p < 0.0033$) (Figure 1).

Statistical correlations between climatic variables and the number of observed reptiles

All climatic variables were log transformed to minimise variation either side of the mean and fit assumptions of the analyses. A correlation matrix (StatView, SAS) produced small positive relationships between reptile counts and log temperature and log absolute humidity (maximum R^2 value 0.315). Further analysis, using logarithmic regression of poisson distributed reptile count data, found no statistically significant ($p > 0.05$) relationship between the number of reptiles and climatic variables (Table 2). The statistical correlation between reptile number and log rainfall was not significant ($R^2 = 0.027$) and therefore was not included in the regression model.

While no significant statistical correlations were found between climatic factors and the numbers of reptiles found in each season, trends are evident when the number of species observed in each season is considered along with the plot of the climatic variables for each season (Figure 1). The highest numbers of reptiles were found during warm, humid conditions, and the lowest numbers were found in the coolest, driest season.

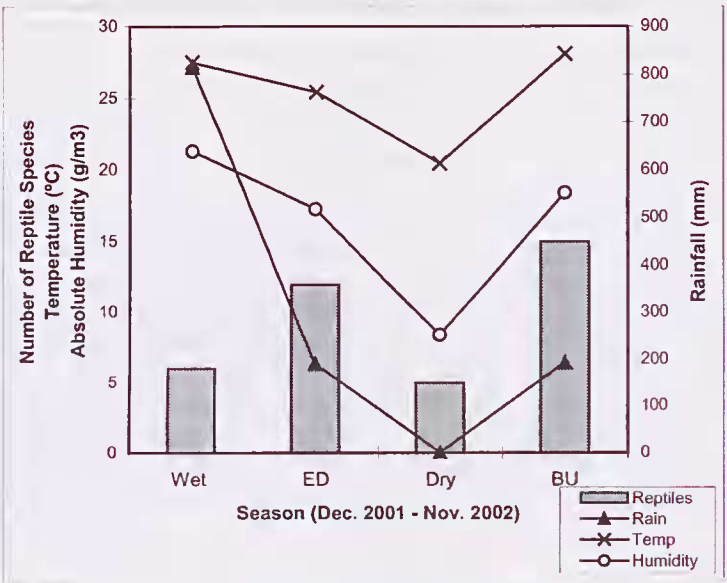

Figure 1. The number of nocturnal reptile species identified in each season and associated climatic variables (ED = early dry; BU = build-up).

Table 2. Reptile counts and climatic variables correlated using logarithmic regression (StatView, SAS). Predictor variables were log transformed, n = 36.

	Coefficient	Standard error	Standard coefficient	R^2	F-Value	p-Value
log temperature	12.790	7.065	0.297	0.088	3.277	0.0791
log humidity	4.394	2.288	0.313	0.098	3.689	0.0632

A list of reptile species in the Robin Falls area

A list of nocturnal species of reptiles reported to inhabit the Robin Falls area is presented in Table 3 (Wilson & Swan 2003, BRS, PWCNT). Half of the nocturnal reptile species (22 of 44) were recorded during one year of regular surveys (asterisks in Table 3). At least 50% of species within most families were recorded on Dorat Road and/or at Robin Falls. Most species of the Elapidae and Pythonidae were recorded (except for the Black-headed Python) but no species of Blind Snake (Typhlopidae) were identified, which is not unusual given their burrowing behaviour (Cogger 2000).

Cane Toad toxins are considered life-threatening to a number of the listed reptiles (Table 3), based on information provided on diet (Wilson & Swan 2003), studies on the effects of toxins on some species of snake (Covacevich & Archer 1975, Phillips *et al.* 2003) and an impact assessment report (van Dam *et al.* 2002). Nearly one third (30%) of nocturnal species of reptile are considered susceptible to the Cane Toad. Only two out of the total species listed are known to be tolerant of *Bufo* toxins: the Keelback Snake *Tropidonophis mairii* and the Slaty-grey Snake *Stegonotus cucullatus* (Ingram & Covacevich 1990, Phillips *et al.* 2003). All other reptiles listed do not appear to prey on amphibians.

Discussion

During this study, 22 species of nocturnal reptiles were identified near Robin Falls. Most species (15) were encountered during the build-up when humidity and temperature were highest. The number of species observed during the early dry was similarly high (11), though there were differences in the types of species encountered. While reptile numbers were much lower in both the wet and dry seasons, field surveys resulted in two additional species (Northern Shovel-nosed Snake and *D. tincta*) being observed in the wet season. Thus, the build-up provides the best opportunity to see nocturnal species of reptiles, but season influences the type of species that may be encountered. As an additional example, the high densities of Arafura File Snakes *A. arafurae* found in Anniversary Creek during the early dry may be predicted following the heavy rains of the wet season because this species is aquatic and inhabits freshwater streams wherever monsoonal floods occur (Cogger 2000).

Based solely on the one year of survey data, we were unable to statistically correlate the climatic conditions of the seasons with the number of reptiles; however there was a clear trend of the greatest numbers of reptiles and species being found in warm, humid seasons and the lowest numbers in the coolest, driest season. Consideration of the physiological requirements of reptiles may provide some explanation of this trend. Reptilian physiology is temperature dependent, and warmer temperatures allow reptiles to metabolise food more quickly for nutrient and water acquisition (Bennett 1982, Andrews & Pough 1985). Many species of reptile limit their activity during the dry season to balance energy requirements and water relationships during less favourable climatic conditions (Christian & Green 1994, Christian & Griffiths 1996, Christian *et al.* 1999). Therefore, the high night-time temperatures and humidity of the wet, build-up and early dry would seem ideal for nocturnal reptilian activity, and the cooler, drier conditions of the dry would be expected to decrease activity and consequently the number of animals observed. In this study, the trend in the numbers of reptiles observed across the seasons supports expectations based on the physiological requirements of reptiles, except during the wet season.

Table 3. Nocturnal reptile species expected to be found in the Robin Falls area (Wilson & Swan 2003, Biological Records Scheme, PWCNT), * introduced species; *** recorded in this study; SCT species susceptible to the Cane Toad (van Dam *et al.* 2002) indicated with an 'x'.

Scientific name	Recorded this study	Common name	SCT
Crocodylidae			
Crocodylus johnstoni	***	Freshwater Crocodile	x
Crocodylus porosus		Saltwater Crocodile	
Chelidae			
Chelodina rugosa		Northern Long-necked Turtle	x
Elseya dentata		Northern Snapping Turtle	
Gekkonidae			
Diplodactylus conspicillatus		Fat-tailed Gecko	
Diplodactylus stenodactylus		Sand-plain Gecko	
Gehyra australis	***	Northern Dtella	
Gehyra nana		Spotted Rock Dtella	
Hemidactylus frenatus *		Asian House Gecko	
Heteronotia binoei	***	Bynoe's Gecko	
Heteronotia planiceps		Northern Cave Gecko	
Nephrurus sheai		Northern Knob-tailed Gecko	
Oedura marmorata	***	Marbled Velvet Gecko	
Oedura rhombifer		Zigzag Velvet Gecko	
Strophurus ciliaris ciliaris	***	Northern Spiny-tailed Gecko	
Pygopodidae			
Delma borea		Northern Snake-lizard	
Delma tincta	***	Black-necked Legless Lizard	
Lialis burtonis	***	Burton's Snake-lizard	
Pygopus steelescotti		Northern Hooded Scaly-foot	
Pygopus nigriceps		Black-headed Scaly-foot	
Typhlopidae			
Ramphotyphlops diversus		Northern Blind Snake	
Ramphotyphlops guentheri		Top End Blind Snake	
Ramphotyphlops ligatus		Robust Blind Snake	
Ramphotyphlops tovelli		Darwin Blind Snake	
Ramphotyphlops unguirostris		Claw-snouted Blind Snake	
Pythonidae			
Antaresia childreni	***	Children's Python	x
Aspidites melanocephalus		Black-headed Python	x
Liasis mackloti	***	Water Python	x
Liasis olivaceus	***	Olive Python	x
Morelia spilota	***	Carpet Python	x
Acrochordidae			
Acrochordus arafurae	***	Arafura File Snake	

Table 3 continued

Scientific name	Recorded this study	Common name	SCT
Colubridae			
Boiga irregularis	***	Brown Tree Snake	x
Enhydris polylepis		Macleay's Water Snake	x
Stegonotus cucullatus	***	Slaty-grey Snake	
Tropidonophis mairii	***	Keelback Snake	
Elapidae			
Acanthophis praelongus	***	Northern Death Adder	x
Brachyurhophis roperi	***	Northern Shovel-nosed Snake	
Rhinoplocephalus pallidiceps	***	Northern Small-eyed Snake	x
Furina ornata	***	Orange-naped Snake	
Pseudechis australis	***	King Brown Snake	x
Pseudonaja nuchalis	***	Western Brown Snake	x
Suta punctata	***	Little Spotted Snake	
Vermicella intermedia	***	Wide-banded Bandy-bandy	
Vermicella multifasciata		Narrow-banded Northern Bandy-bandy	

The significantly higher rainfall during the wet season is an additional factor to consider when attempting to understand the observed trends in reptile numbers associated with climatic variables. The quantity of rain itself is not likely to be the key, but rather the amenable environmental conditions created by excess surface water. The conundrum from this study is that fewer reptiles were observed during the wet season when it would be expected that food resources, such as frogs, would be plentiful. A study on the movements of Water Pythons, Keelbacks and Slaty-grey Snakes at Fogg Dam near Darwin had similar findings in which adults of these species were encountered less often during the wet season than in the dry season (Brown *et al.* 2002). The low density of adult Water Pythons encountered was explained by the migration of their prey, Dusky Rats *Rattus colletti*, which disperse over the floodplain during the wet season. Similarly, in this study, the Northern Death Adder *Acanthophis praelongus* were most commonly encountered along the Robin Falls walking track during the build-up when frog densities were at their highest along the creek, but were not encountered during the wet season when frog densities were at their lowest (McArthur & Young unpubl.). For frogs, it is assumed that the creek provides a permanent water refuge during the dry and build-up, and that the floodplain provides suitable breeding areas during the wet. Therefore, we suspect that Northern Death Adders disperse from the creek to the floodplains during the wet to follow their prey (frogs), as do water pythons (Brown *et al.* 2002). Thus, while counts of reptiles were low during the wet season, it may not be indicative of inactivity but instead an artifact resulting from the seasonal dynamics of the floodplain.

The advantage of choosing two different transects to conduct counts (road and walking track) is that the diversity of habitats sampled is increased and thus the diversity of reptile species encountered is similarly increased. The Brown Tree Snake (or more aptly named the 'Night Tiger') *Boiga irregularis*, and the Carpet Python *Morelia spilota*, were only encountered on the Robin Falls transect. The methods used for each transect were different and, therefore, any analysis directly comparing the number of reptiles encountered per distance between transects would be misleading. Nonetheless, it is worth noting that during the build-up the Robin Falls transect provided more individuals per distance than the Dorat Road transect (2.6 reptiles/km versus 0.22 reptiles/km, respectively). The differenee in habitats (inland monsoon forest with permanent water versus dry floodplain) will likely influence the diversity of reptiles eneountered.

Currently, the Cane Toad at all life stages is a concern, either direetly or indirectly, for native wildlife in the Top End (Covacevich & Archer 1975, Lawler & Hero 1997, Catling *et al.* 1999, Crossland 2000, van Dam *et al.* 2002, Altman *et al.* 2003). Researeh on long-term effeets of the Cane Toad is lacking; however, based on the knowledge of diet preferences, nearly one third (30%) of the nocturnal species of reptilcs local to the Robin Falls area may be susceptiblc to Cane Toad toxins (Covacevich & Archer 1975, van Dam *et al.* 2002, Wilson and Swan 2003; see also Phillips *et al.* 2003). Some reptile species are generalists, such as the Freshwater Croeodilc, and feed on a variety of prey items (including anurans). One study has demonstrated a decline in freshwater crocodile numbcrs in a 'toad invasion zone' area relative to a 'toad free' area, but the same study also demonstrated persistence of the species within arcas where the Cane Toad has a longer history of habitation (Catling *et al.* 1999). Freshwater erocodiles may survive the invasion of the toad given that they either naturally avoid or 'learn' not to select toads as food items. Other speeies, sueh as the Northern Death Adder, and the Children's Python *Antaresia childreni*, are considered to be specialists beeause they feed mainly on frogs, and are more likely to be impacted by the invasion of the Cane Toad. One study has found that the Northern Death Adder need only mouth a Cane Toad to result in death (Covacevieh & Archer 1975).

Only two speeies of reptile are known to be resistant to Canc Toad toxins, the Keelback Snake, and the Slaty-grey Snake (Covaeevieh & Archer 1975, Phillips *et al.* 2003). The Keelback Snakeis one of only a few native predators able to survive *Bufo* toxins at all life stages: eggs, larvae, metamorphs and adults (Ingram & Covacevich 1990, Altman *et al.* 2003, Wilson & Swan 2003). The toleranee of the Keelback Snake to the Canc Toad is 'attributed to thc long evolutionary association of natricines and bufonids' in areas such as North and South America, Asia and Europe, whieh links it with elose relatives in the subfamily Natricinae (Ingram & Covaeevich 1990). Thc future of the other reptiles listed in this study, that are not eonsidered to bc susceptible to Cane Toad toxins, will bc at less risk because these speeies specialise on different prey items. For examplc, thc Northern Shovel-nosed Snake consumes only reptile eggs; the Orange-naped Snake *Furina ornata*, eats exclusively skinks; and the two

bandy-bandys, *Vermicella* spp., feed only on blind snakes (*Ramphotyphlops* spp.) (Cogger 2000).

This study has been useful in providing a list of nocturnal reptiles of the Robin Falls area, which denotes in which season animals were found. Twenty-two species of nocturnal reptile were identified and a total of 90 individuals were observed during 36 survey sessions. While this survey of the Robin Falls area provides very preliminary data on the types of nocturnal reptiles and their numbers, it also provides quantitative information that may prove useful given the imminent arrival of the Cane Toad.

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The Northern Spiny-tailed Gecko *Strophurus ciliaris ciliaris* was recorded near Robin Falls mostly in the dry season. (Lorrae McArthur)

The resemblance of Burton's Snake-lizard *Lialis burtonis* to snakes is superficial. (Lorrae McArthur)

The Wide-banded Bandy-bandy *Vermicella intermedia* feeds exclusively on blind snakes and may thus avoid the direct consequences of Cane Toad toxicity. (Lorrae McArthur)